Int.J.Curr.Microbiol.App.Sci (2017) *6*(10): 3098-3110

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 10 (2017) pp. 3098-3110**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.610.365

Nutrient Management on Crop Productivity and Changes in Soil Organic Carbon and Nutrient Content of Wheat Crop under North West Indo-Gangetic Plains of India

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A B S T R A C T

The aim of this investigation was to prepare and evaluate organic manures and mineral fertilizers with biofertilizer on crop productivity and changes in soil organic carbon (SOC) and nutrient content under a wheat crop. The results demonstrated that the addition of 100% NPK + FYM + PSB + Azotobactor+ Zn + Fe + Mn recorded significantly higher value of growth, yield attributes and micro nutrient content in grain and straw of wheat, plant height (cm), dry matter accumulation (g m^{-1}), grain, straw, biological yield. Higher grain yield was recorded (58.40 q ha^{-1}) followed by 125% NPK + Zn + Mn grain yield (57.9 q ha^{-1}). The available of nitrogen, phosphorus, potassium and micro nutrients (Zn, Fe, Mn) in soil after harvest of crop and content of micronutrinets in grain and straw increase with the combined application of organic and inorganic with biofertilizer. Integration of 100% NPK + FYM + Azotobactor + Zn + Mn + Fe was found more productivity and remvaerative with the higher residual soil fertility status after harvest of wheat crop. Plots amended with manures and 100% NPK + Azotobactor + Zn + Mn + Fe had pronounced impact on improving SOC and nutrient content after the wheat crop indicating that integrated use of manures and mineral fertilizers could be followed to improve and maintain soil fertility, increase crop productivity under intensive cropping system.

Keywords

Nutrient management, FYM, Biofertilizers, Crop productivity.

Article Info

Accepted:
26 September 2017
Available Online:
10 October 2017

Introduction

Sustainable increases in crop production are needed for food security in India as well as in the world. Improving and maintaining soil fertility and quality is of paramount importance to meet the demands of food grain production for an ever-increasing population in the country. There-fore, it is necessary to maintain soil fertility for sustainable production through judicious use of manures and fertilizers. Organic amendments such as recycling of agricultural wastes and application of organic manures have sustained crop production for several thousand years before the introduction of inorganic fertilizers along with the entry of high yielding and fertilizer responsive cultivars that have largely replaced the traditional practices. However, there are many reports that the yield of crops are either stagnate or declined in recent years due to continuous application of mineral fertilizers alone (Manna *et al.,* 2005). The major reason behind this is the decline in soil organic carbon (SOC) which is considered as the most important factor in maintaining soil fertility and sustaining the productivity of agro-ecosystems (Su *et al.,* 2006). The SOC is also the source and sink of atmospheric carbon dioxide (CO_2) and plays a key role in global carbon (C) cycling.

In long-term fertility experiment in India, decline in SOC is generally implicated as one of the cause for yield stagnation, particularly where nitrogen (N) is the only fertilizer, irrespective of cropping system and soil type (Dawe *et al.,* 2000). Therefore, keeping a satisfactory level of SOC is significant for ensuring food security and mitigating climate change. The low contents of SOC, N and phosphorus (P) in sandy loam soils are the major reasons for the deterioration of soil health resulting in low and unsustainable productivity of crops in high intensive cropping systems. The low SOC content of soil is also due to tropical climate and low use or non-use of organics by the farmers of this region. Since organic matter is an important source of N in the soil, these soils are incapable of maintaining N in adequate supply, which also affects crop production. Therefore, any nutrient management practice that can improve organic matter status of soil helps in sustaining crop productivity at higher level.

It has been realized from long-term fertilizer experiments that neither chemical fertilizers nor organic manures alone can achieve sustainability in production, whereas judicious uses of organic manures and inorganic fertilizers are essential to safeguard soil health and augment productivity and input use efficiency which can sustain a highly intensive production system. The positive effect of judicious use of FYM and inorganic fertilizers on productivity of crops has been reported by many workers (Behera *et al.,* 2009; Hati *et al.,* 2006; Bhattacharyya *et al.,* 2008). Though the effect of manures and fertilizers on crop growth and the soil properties has been studied separately, there is very meager information on a holistic study on the effect of integrated use of chemical fertilizers and organic manures on crop growth and soil properties. In India, several long–term fertilizer experiments have indicated wide variability in crop productivity which has been attributed to continuous depletion of soil fertility (Devi *et al.,* (2013). It is hypothesized that improvement in the soil organic carbon and chemical properties of soil due to manure application also influences the crop growth and biomass production, which ultimately influence the productivity and input use efficiency of crops. But there is a paucity of information available on data pertaining to manures prepared using various crop residues and fertilizer applications on SOC and available nutrients on the crop productivity and nutrient use efficiency of crops in the semi-arid tropics of India.

Wheat (*Triticum aestivum* L.), the second most important food crop of the world in terms of area, production and nutrition, meets 20 per cent of the total food, 19 per cent of calories and 20 per cent of protein requirements of the global population besides being a major source of dietary fibre in human nutrition since decades. It was grown in diverse environments across the globe over an area of 277 million hectares producing 654 million metric tons of grains with an average productivity of 3 tons ha^{-1}. In India, wheat occupied an area of 31.0 million hectare and produced of 88.9 million tons of grains with productivity of 2872 kg ha^{-1} during 2015-16 (Anonymous, 2016). Amongst food-grains, it shared about 21 % of area and 34 % production of the country. Keeping this in view, an attempt was made to evaluate influence of organic and inorganic sources on crop productivity, soil organic carbon and nutrient content of wheat crop.

Materials and Methods

The field experiment was conducted during the *rabi* season of 2015-16 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, (29^0 13' N, 77^0 68' 43 E, 237 m above mean sea level) U.P., India. Climate is semi-arid sub-tropical with extremes of hot weather in summer and cold in winter season. There is gradual decrease in mean daily temperature from October reaching as low as 2-4 ^{0}C in January and further a gradual increase is registered from February reaching as high as 43-45 ^{0}C in May. The rains are predominantly caused by south-west monsoon which sets in the last week of June, reaches its peak in July-August and withdraws by the end of September. The area receives 862 mm of rains annually on an average, of which 90% is confined to rainy season (July-September). Meteorological data, *viz.*, rainfall, relative humidity, maximum and minimum temperature, were recorded from Agro-meteorological observatory, of the University, Meerut (Fig. 1).

Soil of experimental field was sandy loam with pH of 8.3, electric conductivity (EC) 1.7 dSm^{-1}, low in organic C (0.41%), available N (174.8 kg ha^{-1}), medium in available P (13.7 kg ha^{-1}) and K (245 kg ha^{-1}). A range of mean weekly maximum temperature varied from 16.5°C to 40.2°C, and the mean weekly minimum temperature ranged from 4.6°C to 22.7°C during 2015-16. The total of 22.4 mm rainfall was received during crop season 2015-16. The experiment was laid out in RBD (Randomized Block design) with three replication. Studies were conducted with fourteen treatments viz., T_1- Control, T_2- 100 % NPK, T_3-75 % NPK + FYM, T_4- 75 % NPK + FYM + PSB+ Azotobactor, T_5- 100 % NPK + Zn, T_6- 100 % NPK + Zn+ Mn, T_7- 100 % NPK + Zn + Mn + Fe, T_8-75 % NPK + FYM+ PSB+ Azotobactor + Zn + Fe + Mn, T_9-125 % NPK, T_{10}- 125% NPK + Zn, T_{11}- 125 % NPK + Zn+ Mn, T_{12}-125% NPK + Zn + Mn + Fe, T_{13}-100% NPK + FYM+ PSB+ Azotobactor + Zn + Fe + Mn and T_{14}-50% N +100%PK + FYM+ PSB+ Azotobactor + Zn + Fe + Mn + LCC based N top dressing. Wheat crop was sown with the row spacing of 22.5 cm. five irrigations (60 mm irrigation in each) were applied at five critical phenological stages. In regards to fertilizer application of the crop, 150 kg N, 75 kg P_2O_5 and 60 kg K_2O were applied as recommended dose. Out of which, 1/2 N and full dose of P_2O_5 and K_2O were applied as basal at the time of sowing by broadcasting method. The remaining 1/2 dose of N was applied in two equal splits at CRI and late tillering stages. Organic manure, FYM, and bio fertilizer Azotobactor and PSB were used as per treatment. Variety of wheat is DBW 17 was sown on 28 November, 2015. The crop was threshed and grain were weighed and presented as quintal per hectare.

A representative sample for grain and straw was taken separately to determine respective dry matter production for each treatment plot wise. The processed plant samples were analyzed by micro-Kjeldahl method to determine nitrogen content. Wet digestion (di-acid) method (Jackson, 1973) was used for preparation of aliquot to determine P, K, Zn and Fe content in plant. However, Fe free glassware was used for Fe determination. N, P and K contents were expressed in percent while Zn, Fe and Mn contents in ppm. Vanado-molybdate yellow colour method was used for phosphorus and flame photometer method for potassium as described by Jackson (1973). Zn, Mn and Fe were determined by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Data on yield attributes, grain yield were recorded at crop maturity. Standard procedures were used for chemical analysis of soil and plant sample.

Statistical analysis

Statistical analysis of data was carried out using standard analysis of variance (Gomez and Gomez, 1984). The significance of the treatment effect was determined using the F-test. To determine the significance of the difference between the means of two treatments, least significant difference (LSD) was computed at $P<0.05$ probability level

Results and Discussion

Growth and yield attributes

Applications of organic with inorganic sources of fertilizer at any level were found to improve the growth and yield attributing character (Table 1) in comparison to control. Nutrient had significant effect on plant height during the year of investigation. Application of different nutrient management practices influenced the plant height significantly over the control. The application of 125% NPK + Zn + Mn + Fe recorded the maximum plant height which was at par with100% NPK + FYM + PSB+ Azotobactor + Zn + Fe + Mn. The control plots resulted significant reduction in plant height compared to other treatments at harvest. Such a higher plant height in 100% NPK with organic manures and bio-fertilizers can be associated with sufficient nutrient supply at the active growth stage. Similar results of increased plant height were also reported by Kumar and Ahlawat (2004), Tulsa Ram and Mir (2006), Thakral *et al.,* (2003). Dry matter production in crop is a function of current photosynthesis. Balanced nutrition helps in achieving higher dry matter accumulation through enhanced canopy cover which ultimately increased higher amount of assimilated through higher rate of current photosynthesis. Total plant stand, plant height, characters will ultimately affect dry matter accumulation by crop. Nutrient management treatments had significant effect on dry matter accumulation. Further, perusal of the data revealed that dry matter accumulation (g m^{-1}) decreased significantly with nutrient doses from 100% NPK with all other nutrient inputs (FYM + Bio fertilizers + micronutrient) to control. At harvest, 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe with all other nutrient inputs crop accumulated more dry matter than other nutrient options. Highest dry matter accumulation was recorded in 125% NPK + Zn + Mn + Fe which was statistically at par with 100% NPK alongwith FYM, biofertilizers, Zn, Mn and Fe at harvest during 2015.16. Minimum dry matter accumulation was recorded in control plots. The application of organic and inorganic sources of nutrients with 100% NPK also produced better growth parameters viz., plant height, and finally dry matter. Similar results were also reported by Jakhar *et al.,* (2006), Sepat *et al.,* (2010).

Yield

The yield of a crop depends upon the source sink relationship and is the cumulative expeession of various growth parameters and yield attributing components. The effect of 100% NPK + FYM+ PSB+ Azotobactor+Zn + Fe + Mn being statistically at par with 125% NPK + Zn + Mn + Fe and was superior to control in respect of yield attributing characters. More yield attributes were found in the treatment where organic and inorganic sources of plant nutrients were applied over control. Higher level of nutrients improved the fertility level of soil and creates congenial condition for better growth and development thus improved the yield attributes. These results are in conformity with those reported by Sen *et al.,* (2003), Singh *et al.,* (2007) and Barthwal *et al.,* (2013). Application of nutrient management treatments significantly increased the grain, yield of wheat during the years of experimentation. The grain, straw and biological yields were recorded significantly higher in the treatments 125% NPK + Zn + Mn + Fe which was 58.70 q ha^{-1} which was at par with 100% NPK + FYM+ PSB+ Azotobacter+Zn + Fe + Mn. The magnitude of increase in grain yield being highest of 30.4 q ha^{-1} or 107% with 125% NPK with Zn + Mn and Fe and 20.9 q ha^{-1} or 73.8% with 100% NPK. Crop grown with 25% substitution of nitrogen through FYM or FYM and biofertilizers gave 2.8 and 4.0% higher yield than that grown with 100% NPK. The crop receiving 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe remaining at par with treatments having 125% NPK with micronutrients proved significantly better than 100% NPK. All the other treatments where 100% NPK was supplemented with micronutrients resulted in significant increase in grain yield over 100% NPK being 5.8% with Zn, 8.7% with Zn + Mn and 9.7% with Zn + Mn + Fe. Further enhancement of NPK to 125% alone or with micronutrients produced significant effect over respective combinations with 100% NPK. Basal application of NPK along with biofertilziers and micro-nutrients coupled with LCC based nitrogen top dressing led to significant increase in yield being 3.8 q ha^{-1} (7.7%) over 100 NPK but remained significantly lower than the yield obtained with 100% NPK, FYM + biofertilizers + micronutrients (58.4 q ha^{-1}). All the other treatments where 100% NPK was supplemented with micronutrients resulted in significant increase in straw yield over 100% NPK being 4.0% with Zn, 7.1% with Zn + Mn and 9.2% with Zn + Mn + Fe. Further enhancement of NPK to 125% alone or with micronutrients produced significant effect over respective combinations with 100% NPK. Crop fertilized with 125% NPK with Zn + Mn and Fe recorded highest biological yield (142.8 q ha^{-1}). The crop receiving 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe remaining at par with biological yield treatments having 125% NPK with micronutrients proved significantly better than 100% NPK. The magnitude of increase was highest of 74.0 q ha^{-1} or 107.5% with 125% NPK + Zn + Mn and Fe and 52.7 q ha^{-1} or 76.5% with 100% NPK over control. The crop receiving 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe remaining at par with treatments having 125% NPK with micronutrients proved significantly better than 100% NPK. The beneficial effect of organic manures on grain, yields and yield attributing characters might be assigned to the fact that after proper decomposition and mineralization, these manures supplemented plant nutrients to the plants and also had solublising effect on fixed forms of nutrients in soil. Similar findings were also reported by Mubarak and Singh, (2011).The combination use of organic manures and chemical fertilizers enhanced the inherent capacity of soil as reported by Pandey *et al.*, (2009), Verma, *et al.*, (2010) and Meena *et al.*, (2012), Singh and Singh (2005).

Available nutrients and contents

Soil residual fertility exhibited significant variation under different nutrient management practices attributed to differential crop removals and additions. Available nitrogen, phosphorus, potassium, zinc, manganese, iron and organic carbon varied from 201.5 to 225.7 kg ha^{-1}, 12.4 to 17.2 kg $ha^{-1,}$ 175.6 to 195.5 kg $ha^{-1,}$ 0.81 to 1.15 mg ha^{-1}, 2.85 to 4.37 mg kg^{-1}, 3.10 mg kg^{-1} to 4.14 mg $kg^{-1}$and 0.39 to 0.53 % after harvest of wheat, the lowest being with control and the highest with the use of 125% NPK + Zn + Mn + Fe. Applications of Zn, Mn and Fe alone or together with 100% NPK increased significantly the available nitrogen in soil over 100% NPK possibly due to better root growth. Application of bio-fertilizers benefited the soil significantly in respect of available nitrogen and phosphorus. Available soil nutrients (organic carbon, available N, P, K, Zn, Mn and Fe) were significantly lower in unfertilized plots as against highest in plots receiving 125% NPK + Zn + Mn + Fe remained at par with 100% NPK along with FYM, biofertilizers, Zn, Mn, Fe proved significantly better than 100% NPK. A positive nutrient balance in soil with application of NPK has been noticed by Sharma (2005), with FYM by Kumar *et al.*, (2003), Singh and Singh (2003), with Zn with *Azotobacter* by Sarma *et al.*, (2007) and with PSB by Singh and Pal (2011).

Table.1 Plant height, Dry matter accumulation, grain, straw, biological yield and net return as influenced by different nutrient options

Treatments	**Plant height at harvest (cm)**	**Dry matter accumulation (g) m^{-1} at harvest**	**Grain Yield (q ha^{-1})**	**Straw Yield (q ha^{-1})**	**Biological Yield (q ha^{-1})**	**Net returns (Rs ha^{-1})**
T_1- Control	61.5	678.0	28.3	40.5	68.8	24740
T_2-100 % NPK	75.2	1007.4	49.2	72.3	121.5	66385
T_3-75 % NPK + FYM	75.9	1010.8	50.6	73.9	124.5	69143
T_4-75 % NPK + FYM + PSB+ Azotobactor	76.4	1012.1	51.2	74.8	126.0	70123
T_5-100 % NPK + Zn	77.2	1014.4	52.1	75.2	127.3	71080
T_6-100 % NPK + Zn+ Mn	78.6	1017.4	53.5	77.5	131.0	72900
T_7-100 % NPK + Zn + Mn + Fe	80.2	1021.2	54.0	79.0	133.0	73175
T_8-75 % NPK + FYM+ PSB+ Azotobactor+ Zn + Fe + Mn	78.3	1013.0	53.3	77.3	130.6	70628
T_9-125 % NPK	84.5	1077.1	53.2	79.2	132.4	74374
T_{10}-125% NPK + Zn	84.8	1078.4	56.3	81.5	137.8	79079
T_{11}-125 % NPK + Zn+ Mn	85.1	1079.3	57.9	82.9	140.8	80168
T_{12}-125% NPK + Zn + Mn + Fe	86.6	1081.5	58.7	84.1	142.8	81349
T_{13}-100% NPK + FYM+ PSB+ Azotobactor+Zn + Fe+Mn	85.3	1080.2	58.4	83.9	142.3	80170
T_{14}-50% N +100%PK + FYM+PSB+ Azotobactor+Zn + Fe + Mn + LCC based N top dressing	77.5	1018.7	53.0	76.8	129.8	71260
LSD P<0.05	7.2	52.1	2.6	4.5	9.2	

Table.2 Effect of nutrient management on available macro and micro nutrients in soil after harvest

Treatments	**Available macronutrient (kg ha^{-1})**			**Available micronutrients (mg kg^{-1})**			**Organic carbon (%)**
	N	**P**	**K**	**Zn**	**Fe**	**Mn**	
T_1- Control	173.5	12.4	235.6	0.81	2.85	3.10	0.39
T_2-100 % NPK	180.3	13.8	240.8	0.84	3.61	3.51	0.41
T_3-75 % NPK + FYM	185.3	14.1	241.2	0.86	3.69	3.56	0.45
T_4-75 % NPK + FYM + PSB+ Azotobactor	186.7	14.1	242.7	0.88	3.75	3.59	0.48
T_5-100 % NPK + Zn	181.1	13.3	243.4	0.91	3.82	3.65	0.40
T_6-100 % NPK + Zn+ Mn	180.3	13.5	243.6	0.98	4.03	3.83	0.42
T_7-100 % NPK + Zn + Mn + Fe	181.2	13.6	243.7	1.01	4.09	3.88	0.44
T_8-75 % NPK + FYM+ PSB+ Azotobactor+ Zn + Fe + Mn	184.4	14.2	242.4	0.95	3.95	3.76	0.49
T_9-125 % NPK	182.3	13.7	244.0	1.04	4.15	3.95	0.46
T_{10}-125% NPK + Zn	182.4	13.8	244.2	1.06	4.22	4.01	0.47
T_{11}-125 % NPK + Zn+ Mn	183.1	13.9	244.3	1.09	4.27	4.06	0.48
T_{12}-125% NPK + Zn + Mn + Fe	183.6	14.1	244.6	1.15	4.37	4.14	0.50
T_{13}-100% NPK + FYM+ PSB+ Azotobactor+Zn + Fe +Mn	185.6	17.2	245.2	1.12	4.31	4.09	0.53
T_{14}-50% N +100%PK + FYM+PSB+ Azotobactor+Zn + Fe + Mn + LCC based N top dressing	181.1	16.3	243.3	0.93	3.89	3.69	0.48
LSD P<0.05	8.2	1.2	5.4	0.12	0.66	NS	0.05

Table.3 Effect of nutrient management on Zn, Mn and Fe content in grain and straw

Treatments	**Zn content (ppm)**		**Mn content (ppm)**		**Fe content (ppm)**	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_1- Control	32.5	25.0	25.4	14.2	45.3	135.0
T_2-100 % NPK	47.6	29.8	34.8	20.9	59.9	165.2
T_3-75 % NPK + FYM	48.0	30.2	35.1	21.1	60.0	165.4
T_4-75 % NPK + FYM + PSB+ Azotobacter	48.9	30.5	35.3	21.3	60.2	165.6
T_5-100 % NPK + Zn	49.6	31.0	35.6	21.9	60.5	165.8
T_6-100 % NPK + Zn+ Mn	50.1	31.9	36.1	22.2	60.7	166.0
T_7-100 % NPK + Zn + Mn + Fe	50.2	32.1	36.3	22.6	61.2	167.5
T_8-75 % NPK + FYM+ PSB+ Azotobacter+ Zn + Fe + Mn	50.0	31.7	35.9	22.0	62.1	167.1
T_9-125 % NPK	49.4	32.0	35.7	21.5	62.9	166.2
T_{10}-125% NPK + Zn	51.6	32.8	35.9	21.8	63.0	166.5
T_{11}-125 % NPK + Zn+ Mn	53.2	33.0	36.3	22.6	64.1	167.6
T_{12}-125% NPK + Zn + Mn + Fe	54.5	33.4	36.7	23.1	64.5	168.0
T_{13}-100% NPK + FYM+ PSB+ Azotobacter+Zn + Fe +Mn	53.8	33.1	36.5	22.9	63.4	166.7
T_{14}-50% N +100%PK + FYM+PSB+ Azotobacter+Zn + Fe + Mn + LCC based N top dressing	49.8	31.3	35.7	21.9	62.7	166.8
LSD P<0.05	1.4	1.2	1.0	1.2	3.5	1.2

Fig.1 Weekly meteorological data during crop period (November 2015 - April 2016)

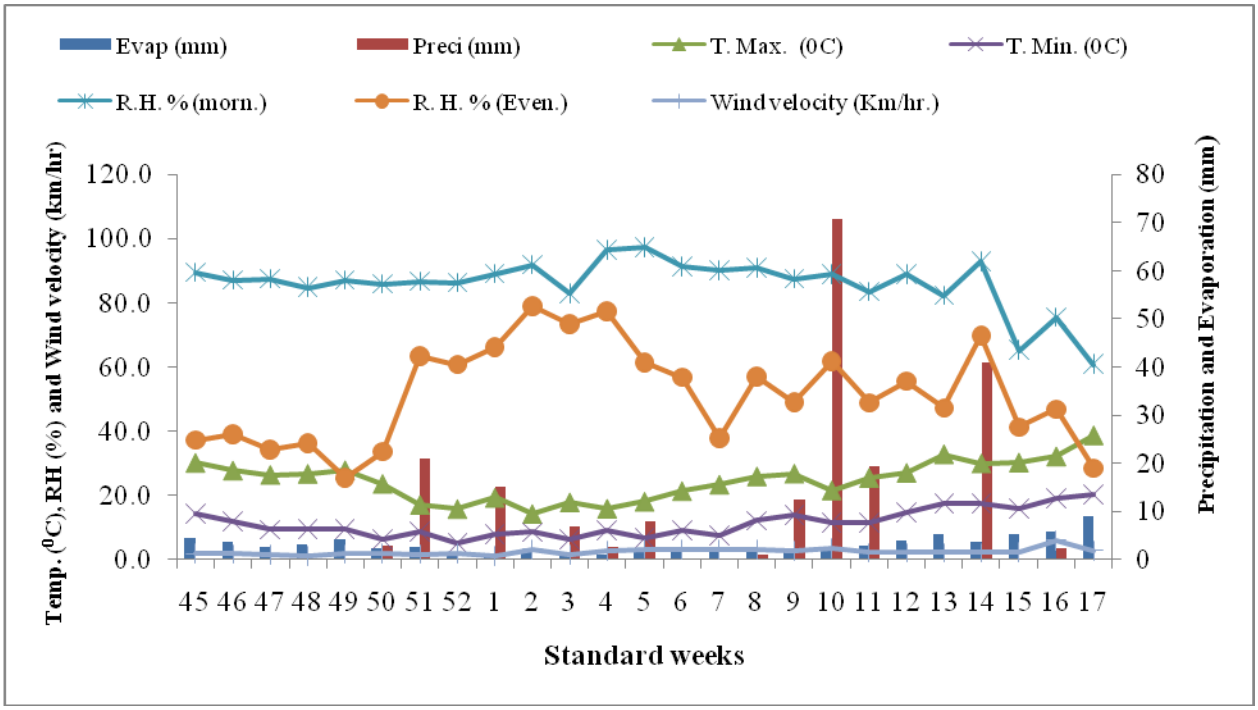
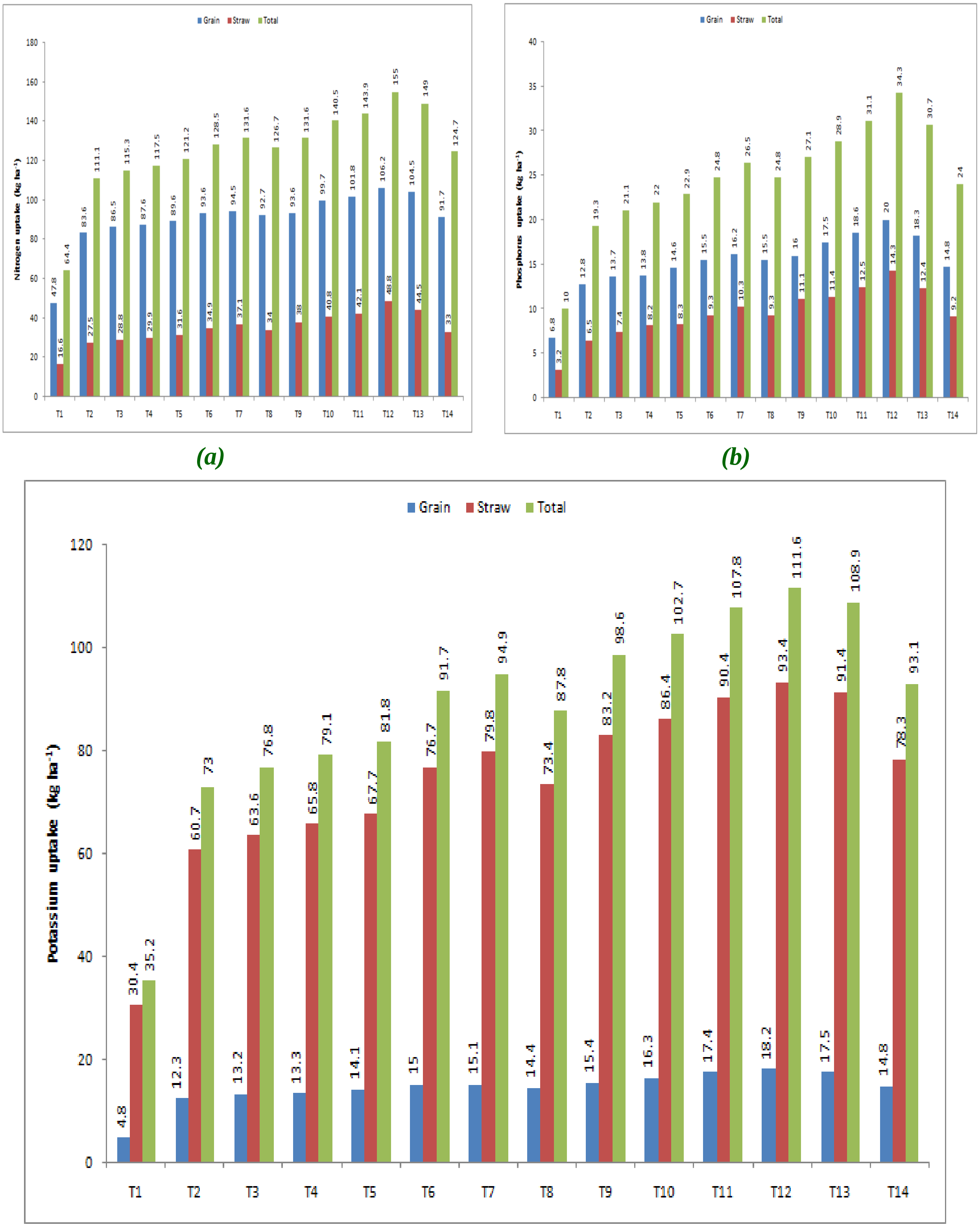


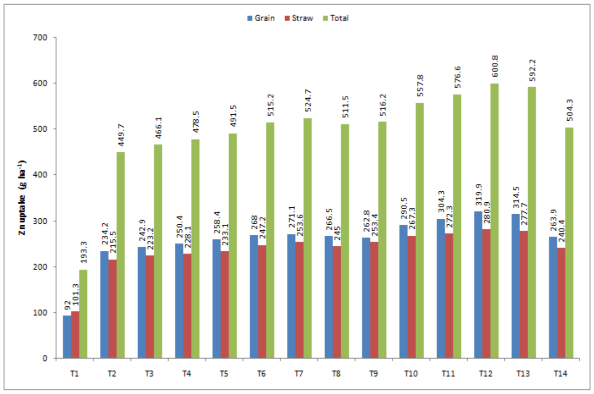
Fig.2 Effect of nutrient management practices in grains, straw and total nitrogen (a), total phosphorus (b) and total potassium uptake (c) (kg ha^{-1})



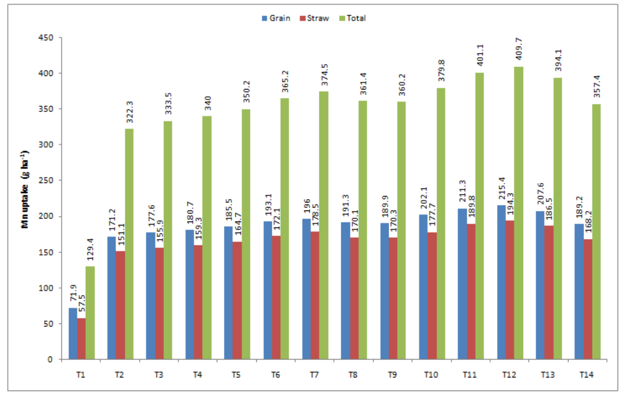
(a) *(b)*

(c)

Fig.3 Effect of nutrient management practices in grains, straw and total zinc (a), total manganese (b), total iron (c) uptake (g ha^{-1}) and soil organic carbon (%) (d) after crop harvest



(a)



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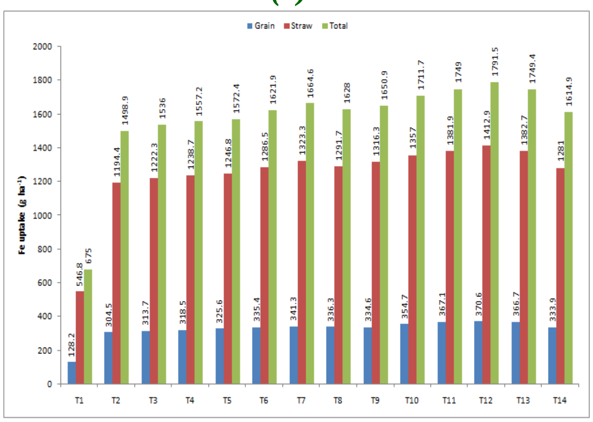
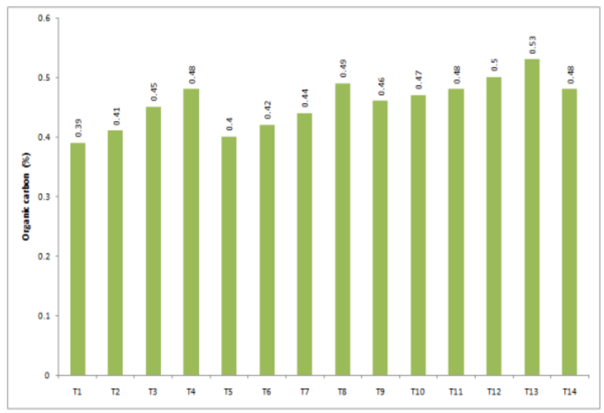
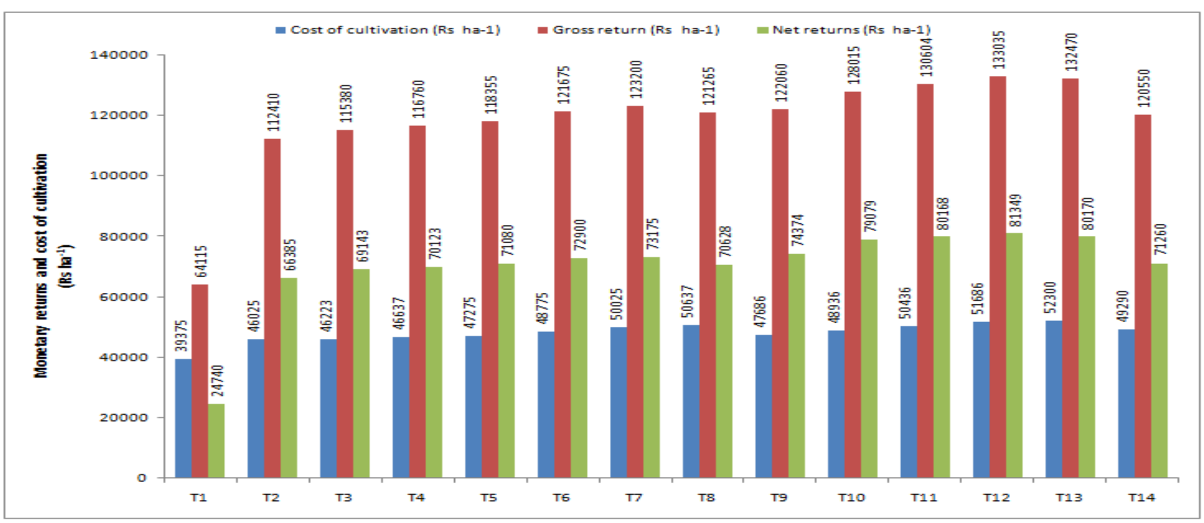


(c)



(d)

Fig.4 Effect of nutrient management on Cost of cultivation, Gross return and Net returns (Rs ha^{-1})



The nutrient content in grain and straw was significantly influenced by nutrient management practices. The content of N, P, K, Zn, Mn and Fe varied from 1.45 to 1.81%, 0.24 to 0.34%, 0.17 to 0.31%, 32.5 to 54.5 ppm, 25.4 to 36.7 ppm and 45.3 to 64.5 ppm in grain respectively, the highest, being in crop receiving 125% NPK + Zn + Mn + Fe and lowest with no nutrient application. Respective content in straw ranged from 0.31 to 0.58%, 0.08 to 0.17%, 0.75 to 1.11%, 25.0 to 33.4 ppm, 14.2 to 23.1 ppm and 135.0 to 168.0 ppm again being the highest with 125% NPK + Zn + Mn + Fe remained at par with 100% NPK along with FYM, biofertilizers, Zn, Mn, Fe proved significantly better than 100% NPK and lowest with no nutrient application. Applications of Zn, Mn and Fe alone or together with 100% NPK increased contents in grains and straw over 100% NPK (Tables 2 and 3). Though, the increase was significant with Zn only in grains and with Mn & Fe only in straw. This is in accordance to the kind of relationship between nutrient content in plant tissues and the concentration in growing medium, the soil. Application of fertilizers readily increases the availability of nutrient concerned in the soil solution thereby enhancing its absorption by the plant roots and further translocation to the site of action. Application of bio-fertilizer could not bring any significant difference in contents either of grains or straw. Favorable effect of NPK on nutrient content of wheat has also been noted by Shivay *et al.,* 2008), Singh and Kumar (2010) Kumar and Pannu (2012). The beneficial effect of Zn and B when applied in conjunction with organic/inorganic/bio-fertilizers might have helped in increasing and balancing the availability of essential plant nutrients and organic fertilizers sustained it over a long time. Microbial decomposition of organic manure (FYM) with simultaneous release of organic acid which act as chelating agent might have facilitated the availability and absorption of micro-nutrients as indicated by plant nutrient content and residual soil fertility (Figs. 2 and 3).

Economic

Net return was observed highest in treatment 125% NPK + Zn + Mn + Fe closely followed by 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe. The lowest net return was observed in control plots. Due to higher grain yield, the net income was also higher with use of organic and inorganic fertilizers over 100% NPK. Similar result was also reported by Bhaduri and Gautam (2012) and Lone *et al.,* (2011) (Fig. 4).

The present results clearly indicated that productivity of maize and wheat increased significantly due to application of organic manures and chemical fertilizers either alone or in combination compared to unfertilized control. Conjoint use of organic manures and mineral fertilizers significantly enhanced soil organic carbon (SOC) than unfertilized control plot after maize and wheat harvest. It may be concluded that the highest growth characters recorded with 125% NPK + Zn + Mn + Fe was statistically similar to the treatment of 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe and significantly higher than 100% NPK and control. Although application of 125% NPK + Zn + Mn + Fe yielded more among all the nutrient management options but it was found at par with 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe in grain, straw and biological yield and net return. In view of the available macro and micro nutrients and content of micro nutrients in grain and straw. Application of 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe was found best among all nutrient management options. Keeping in view the sustainability of soil health 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe proved better. Thus 100% NPK along with FYM, biofertilizers, Zn, Mn and Fe may be suggested for good performance of wheat crop and sustainability of soil health and crop yield in future.

Acknowledgement

The author thanks the, Department of Agronomy, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) for providing facilities for successful completion of the research works.

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How to cite this article:

Vineet Singh, N.S. Rana, Vivek, B.P. Dhyani, Ravindra Kumar, R.K. Naresh, Arun Kumar, Saurabh Tyagi and Nihal Chandra Mahajan. 2017. Nutrient Management on Crop Productivity and Changes in Soil Organic Carbon and Nutrient Content of Wheat Crop under North West Indo-Gangetic Plains of India. *Int.J.Curr.Microbiol.App.Sci*. 6(10): 3098-3110.
doi: https://doi.org/10.20546/ijcmas.2017.610.365